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DIAMOND DRILLING BLAST HOLES

EASTERN MANGETITE MINE A

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McHENRY MOSIER

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DIAMOND DRILLING BLAST HOLES, EASTERN MAGNETITE MINE A[1]

By McHenry Mosier[2]

SUMMARY

This paper describes the practice in diamond drilling blast holes and discusses the relative merits of this method as compared with drilling by percussion rock-drills at eastern magnetite mine A.

The rocks that were drilled included: (1) Gneiss; (2) schist; (3) crystalline limestone; and (4) granular masses of magnetite.

The principal stoping methods were: (1) Sublevel open stoping and (2) inclined room-and-pillar. Diamond drilling was used in the sublevel stopes and in some of the large pillars in an old section of the mine.

Experimental work on diamond drilling blast holes began in 1943. Drilling proved difficult owing to the occurrence of fingers of extremely hard barren rock in the magnetite ore. All diamond drilling was contracted to a firm that furnished everything necessary for drilling except compressed air and water.

In most instances the diamond-drill machine is clamped directly to a 3.5-inch column to reduce vibration. For drilling in floor pillars in open stopes, the drill was set on a demountable, sectionalized steel frame with four legs carrying a 20-foot, 3.5-inch, extra-heavy pipe.

Both coring and noncoring bits were tried. In holes drilled with a coring bit, the core was ground into sludge as the bit advanced so that it was unnecessary to delay drilling for pulling core.

Data on tests with several types of bits are given as well as some operating results. A direct comparison of costs between diamond drilling and percussion drilling was not available.

The advantages of diamond drilling blast holes at mine A included:

(1) Safer working conditions in open stopes.
(2) The recovery of additional ore.
(3) A reduction in the amount of stope development.

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(4) A continuous maximum production from stopes.
(5) Virtual elimination of dust from drilling.

The disadvantages were:

(1) Greater capital investment.
(2) In blasting, more skill is required to load and detonate the charge in long holes.

Diamond drilling in mine A appeared more advantageous than percussion in certain blocks where the mining method was favorable for diamond drilling.

INTRODUCTION

This paper is one of a series undertaken by the Mining Branch of the Bureau of Mines to describe current practice in diamond drilling for production purposes at various mines throughout the United States, and to discuss the relative merits of this method as compared with drilling by percussion rock drills.

The Bureau of Mines and the mining companies that cooperate in this investigation have the common objective of developing information on this type of drilling and making it available to all who may be interested in the possible improvement of mining operations.

HISTORY OF THE MINE A DISTRICT

The first real mining activity in the district was during the American Revolution. Production gradually increased until the discovery of the iron ranges in Minnesota in 1890, when, for economic reasons, the output of the district was reduced to operations of minor importance. However, beginning in the period immediately preceding World War II, conditions with respect to steel production warranted increased interest in the production of eastern magnetites. Currently, their value in a large measure depends: (1) Upon the ratio of concentration of the crude ore mined to the merchantable product shipped; and (2) upon the purity of this product.

GEOLOGY

The following description of the geology of mine A is an abstract from an official State publication:

> The wall rocks include: (1) Gneisses, ranging from granitic to dionitic composition; and a (2) series of sedimentary metamorphics comprising hornblende and biotite schists, and crystalline limestones. The ores are granular masses of magnetite. They have been formed by igneous action, particularly by syenites and granites. They occur in layers that conform to the foliation of the enclosing rocks, which have been mashed and folded in complex, involved curves.

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MINING METHODS

Mine A was developed by inclined shafts on a 25° to 30° slope. Levels were driven at 300-foot intervals on the dip. Haulage drifts were 9 by 12 feet and were connected at irregular intervals by raises 6 by 8 feet in cross section that followed the hanging wall.

The principal stoping methods were: (1) Sublevel open stoping; and (2) inclined room-and-pillar. Diamond drilling was used in the sublevel stopes. The broken ore was removed by scraping from finger raises in scram drifts directly into 10-ton Granby-type cars. A scraper sublevel ran from the back of each haulage level. Two other sublevels were spaced at 50-foot vertical intervals.

In opening the first stope on a new level, a slot was cut across the entire width of the ore body into which ore was broken by blasting, and vertical rings of holes were drilled normal to the longitudinal axis of the stope. The rings were spaced at 7-foot intervals with two reliever holes midway between rings. These two holes were blasted together, followed by the corresponding holes in the next ring and then successively each hole, retreating simultaneously from both sides of this break, to the completion of the ring.

Rings were blasted with a semigelatin dynamite with a strength of 60 percent. Block holing was accomplished with the same type of dynamite, but with a strength of 40 percent. In ring drilling, the proper sequence in firing the holes was obtained by cutting the fuse to appropriate lengths. Radiating holes were loaded from the bottom to a point about 3 feet distant from the powder in an adjoining hole. No stemming was used.

Drilling in the inclined room-and-pillar method was by percussion rock drills. Some of the large pillars in an old section of the mine were diamond-drilled, and all holes in an entire pillar were blasted simultaneously.

DIAMOND DRILLING

Experimental work on diamond drilling blast holes was begun in 1943. This method has been applied to sublevel stoping and to the recovery of both floor and vertical pillars. Drilling proved difficult, owing to the occurrence of fingers of nearly barren rock in the magnetite ore. These fingers were so much harder than the ore that in many instances they ruined a diamond bit before the drill could be stopped.

All diamond drilling was contracted to a firm which furnished operating labor, equipment, diamond bits, and supplies. The mining company supplied compressed air and water at the drill and assisted the contractor when a new set-up involved a long move. The contract price was $0.80 per foot.

EQUIPMENT

The maximum number of diamond-drill machines used on blast-hole work at any time was three. Two additional machines were on hand. The machines were all gear-driven and were of two makes with the following specifications:

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Item	Drill A	Drill B
Air motor:		
Type	Rotary	Rotary
Horsepower at 80 pounds air pressure	5	10
Feed:		
Type	Screw	Screw
Run (length in inches)	24	27
Revolutions per inch of bit advance	100-800	100-1,200
Bit speed (range, r.p.m.)	0-1,500	0-3,300
Weight of drill (pounds)	160	155
Capacity (EX rods - feet)	500	500

A few rods with quick-break threads and fewer turns were used with one of the drill machines. These were reported to have saved time in drilling. However, as there was a possibility of losing the end rod with its diamond bit when a down-hole drilled into a mine opening, their use was limited to holes that bottomed in solid ground. Rod pullers have not been found necessary on blast-hole drilling at mine A, as the holes were less than 100 feet in length.

A convex pilot bit was developed at mine A which showed some advantage over the usual concave design in drilling ground with alternating hard and soft streaks because penetration was faster and diamond loss was reduced.

For charging dynamite, a patented, tamping stick, 1 inch in diameter, in 6-foot sections joined with an interlocking hook was used, so that any required length could be easily assembled as the stick was being inserted in the drill hole and quickly disconnected when it was withdrawn.

SET-UP

In most instances the diamond-drill machine clamped directly to a 3.5-inch column to reduce vibration. Various set-ups have been tried but discarded, owing to excessive vibration which decreased the life of the bit and the equipment.

In sublevel stoping, an engineer with a transit laid out rings for drilling, marked them by narrow paint lines on both walls of the sublevel, and furnished a sketch of each ring to the driller.

The driller, usually without further engineering assistance, alined each hole for azimuth by the paint lines and set the inclination by a combination rule, level, and protractor.

Where the set-up was on a floor covered with loose muck and to prevent caving of the collar of the hole or the introduction of muck into the hole, down-holes were drilled with an AX starter-bit to a depth of 6 to 12 inches when a 1.5-inch pipe, 12 to 18 inches long, was inserted. This proved effective because it supported the ground around the collar and extended above the loose muck. Upon their completion, all holes, including those with pipe set in the collar, were sealed with a tapered wooden plug to keep the hole clean.

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In drilling one floor pillar in an open stope where the back was too high for the use of a column, the drill was set on a demountable, sectionalized steel frame with four legs carrying a 20-foot, 3.5-inch extra-heavy pipe. The machine was clamped to this pipe, which was 3.5 feet above the floor. Four rings on 5-foot intervals could be drilled from one position of the frame by moving the machine along the pipe. The frame was stabilized by four cables with turnbuckles attached to eyebolts set in the floor. This frame was also used when drilling on top of a vertical pillar, where a column could not be securely blocked.

The standard length of rods was 2 feet. A 2-foot core barrel was used to start the hole, after which a 5-foot, single-tube core barrel was substituted to maintain alinement of the hole.

OPERATING DATA

In ring drilling, which has amounted to about 90 percent of the total diamond drilling, inclination of holes ranged from vertical down-holes through horizontal holes to vertical up-holes. Both coring and noncoring bits were tried. In holes drilled with a coring bit, the core was not pulled when drilling in ore but was ground into sludge as the bit advanced, so that is was unnecessary to delay drilling by pulling core.

Measurement of the amount of drill water was not made but an ample supply at a good pressure was imperative. More water was required than for percussion machines. Water pressure underground ranged from 100 to 250 pounds. Air pressure at the machine ranged from 90 to 100 pounds.

It was desirable, wherever possible, to connect drill holes with the stope below. This drained the drill hole, checked the estimated thickness of the intervening ore, and obviated the necessity of cleaning the hole before charging. To measure the depth of these holes, the paper from a box of powder was twisted into a roll that fitted tightly in the drill hole. The paper was then pushed through the hole, and the depth determined by the "feel" when the paper dropped into the opening below. A second paper was then prepared and pushed to the bottom of the drill hole as previously measured, where it was left as a plug to prevent loss of powder when loading the drill hole. To make the paper plug hold firmly, a handful of dry, fine ore was dropped into the hole before charging. The first few sticks of dynamite were pressed more gently than those that followed.

RESULTS OF DIAMOND DRILLING

Several tests have been run with various types of EX bits which produced a hole 1.5 inches in diameter. 218 noncoring cast bits, with a concave pilot, drilled 9,177 feet and had an average life of 42.1 feet. The range was 1.6 to 120 feet. Fifty coring cast bits, with the same composition as the pilot bit, drilled 850 feet and averaged 17.0 feet.

With another type of noncoring pilot bit, 27 bits drilled 1,286 feet and averaged 47.0 feet per bit.

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In a special test on coring bits of a third type, a selected operator ran the diamond drill 6 consecutive days and attained an average advance of 89.5 feet per machine shift. The life of the bits averaged 50 feet.

In a recent test with a gear-driven, diamond-drill machine of standard design using one of the common brands of impregnated, cast coring bits with no large stones, sand-blasting equipment for reconditioning bits was install on the surface near the collar of the shaft. Coarse-grained magnetite, char acteristic of mine A, tended to sharpen the bit. In contrast to this effect drilling in fine-grained, crystalline magnetite may require more frequent re conditioning of the bits. Following the usual practice of blast-hole drill- ing at mine A when drilling in ore, the core was ground to sludge in the cor barrel. However, in drilling barren rock, owing to its hardness the core could not be ground during drilling and had to be pulled.

One of these cast bits drilled 63 feet in ore the first shift without reconditioning. On the next shift, owing to a rock finger, a new bit drille only 11 feet when it needed sand blasting. On the third shift, 36 feet were drilled after many delays from various causes, including loss of time by the driller while sand-blasting both the above bits. In this test, which com- prised 22 drill shifts, the average advance per drill shift was 40.5 feet, including delays from all causes. Much time was lost in drilling because of experimental trials and changes in operating technique and the lack of ade- quate equipment and bits to insure continuous operation. This test was run in ground with more than the amount of barren rock fingers usually found in stoping areas. The maximum advance per machine shift was 94 feet, which in- cluded setting up the drill twice and sand-blasting the bit three times.

In magnetite ore, a third bit ran 72 feet in one hole without pulling the rods, plus an additional 6 feet in another hole, before sand blasting was necessary. This bit drilled 531 feet. The distance drilled per sand blast ranged from 1 to 78 feet and averaged 14 feet. The short runs were due to hard rock fingers. The bit replacement cost was $0.17 per foot drilled. A second bit of this type was still in good condition at 362 feet.

In one block of sublevel stoping which was completed in 1945, the weighed ore extracted was 76,916 gross tons (2,240 pounds). The diamond drilling totaled 21,175 feet; and the total powder, including blockholing, was 15,950 pounds. Sixty-percent semigelatin dynamite was used in primary blasting and 40 percent in blockholing. The tonnage per foot of diamond- drill hole was 3.6, and the tons broken per pound of powder 4.8. The tons per machine-man-hour was 12.5. In this block, 425 drill shifts were re- quired. The feet drilled per shift was 49.8, and the feet per bit was 28. The length of the holes ranged from 15 to 70 feet.

In mine A, during the calendar year 1945, 25,333 feet was diamond- drilled in 703 holes with 955 man-shifts. The average feet drilled per machine-man-shift was 26.5, and the average advance per diamond-drill shift was 48.2 feet. The crew on about 90 percent of the drill shifts consisted of a drill operator and a helper, while on the remaining shifts, only one operator worked. The average depth of hole was 36 feet. The distance drilled per bit was 50 feet. The diamond loss approximated 2.0 carats per bit or 0.04 carat per foot. On the $6.00 grade of diamond, this loss amounte to $0.24 per foot.

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In 1945, about 12 percent of all the ore from the mine was produced by diamond drilling.

PERCUSSION ROCK DRILLS

A direct comparison of operating data between diamond drilling and percussion drilling could not be made at mine A, because data on diamond drilling were obtained in sublevel stopes, and no similar stope has been worked entirely by percussion drills from its beginning to its completion.

All percussion drilling in both development headings and stopes was with detachable bits and 1-inch hexagon steel. Starter bits were 2 inches in diameter. Both hand-held and mounted, wet, sinker drills were used for benchwork in stopes. For the entire property, including both stopes and development, 90 tons of ore was produced per machine-shift; and as there was one operator on a machine, 90 tons of ore was also produced per machine-man-shift. This was equivalent to 11.25 tons per machine-man-hour. The footage of hole drilled was not measured because payments to miners were on a basic rate per hour plus a sliding scale per ton of ore produced. This included drilling, blasting, scraping, and tramming to an ore pass. However, it was estimated that a miner averaged 6 down-holes, each 15 feet in depth, or 90 feet per shift.

Sixty percent semigelatin dynamite was used in development headings and 40 percent strength in stoping operations. Cartridges were 1-1/4 by 8 inches. All blasting was with safety fuse and No. 6 caps.

MERITS OF DIAMOND-DRILLING BLAST HOLES AT MINE A COMPARED TO PERCUSSION DRILLING

The advantages in the use of the diamond drills for blast holes in stopes were:

(1) Working conditions in open stopes have proved to be safer because the driller was closer to the back, which came under continuous observation.

(2) Additional ore was recovered as certain floor pillars, which would not support a drill set-up, could be drilled from a safe place in adjacent ground.

(3) A reduction in the amount of stope development resulted by increasing the vertical interval between sublevels to 50 feet. This was made possible by long diamond-drill holes.

(4) Continuous maximum production was assured by diamond drilling well in advance of blasting requirements.

(5) Dust from drilling was virtually eliminated.

(6) Traffic through the hoisting shaft was reduced because less steel and supplies were needed for drilling.

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The disadvantages were:

(1) The capital investment for equipment was greater.

(2) Blasting long holes required more skill to load and detonate the charge.

(3) The equipment had to be handled with greater care.

(4) Drilling could not be completely standardized because diamond drilling had only limited application while percussion drilling continued in much of the mine work, notably in development headings and in some types of stoping.

CONCLUSIONS

Although primary costs were not available for direct comparisons, diamond drilling blast holes in stopes in mine A appeared more advantageous than percussion drilling in certain blocks where the mining method was favorable for the use of long holes.

With the benefit of additional experience and the acquisition of a greater degree of standardization in operating techniques, further improvement in blast-hole diamond drilling may be anticipated in mine A over the pioneer work done in 1945.

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